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Exploring stakeholder engagement in urban village renovation projects through a mixed-method approach to social network analysis: a case study of Tianjin

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The stakeholder relationship network in urban village renovation projects is highly complex, exhibiting dynamic changes at different stages. Therefore, exploring the characteristics of the interaction networks among stakeholders at each stage and the changes in their role positioning is crucial for achieving collaborative governance involving multiple stakeholders. By employing a mixed research methodology comprising single-case analysis and social network analysis, this study aimed to explore stakeholder networks' characteristics and evolution patterns at each stage of the renovation project. Moreover, it seeks to identify breakthroughs for collaborative governance. The research revealed that the main constraints to stakeholder collaboration in urban village renovation projects are low public participation in the early preparation stage, weak network situation of stakeholders during the demolition and resettlement compensation stage, and significant clique fragmentation during the development and construction implementation stages. This study recommended approaches such as transforming the development model, establishing public status, leveraging the resource-driving advantages of core stakeholders, and establishing a network-sharing platform. Through these means, various stakeholders could be guided to be effectively involved in the entire project construction process, leading to deep cooperation among multiple stakeholders.

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Introduction

As China's urbanization accelerates, cities are gradually shifting towards redeveloping existing assets. Urban village renovation has become an important initiative for enhancing high-quality urban development (Pan and Du, 2021). Researchers estimated that the investment scale in urban renewal would be expected to reach 9.2 trillion yuan by 2030, accounting for approximately 11% of gross fixed capital formation (Xu, 2021). However, urban villages, as non-standardized construction areas, present prominent challenges compared to typical urban renewal projects, including complex stakeholder interest, unclear property rights, diverse transformation goals, and weak governance levels. Moreover, the distinct demands of various stakeholders, such as the government, developers, and residents, can lead to severe negative impacts if mishandled (Yu et al. 2019, Zhu et al. 2022). In the practice of urban village renovation, incidents like violent demolitions and mass protests are not uncommon (Mai et al. 2022, Yu et al. 2017). The coordinative nature of stakeholder relationships plays an essential role in urban village renovation projects (Cao and Deng, 2021). Different stakeholders are not independent but interdependent and play diverse roles in decision-making in the process of urban village renovation (Zhuang et al. 2019). It has also been shown that collaborative governance among stakeholders is key to addressing management issues in urban village renovation (Li et al. 2020, Liu et al. 2021). Therefore, clarifying the complex role of various stakeholders in renovation projects and exploring diverse collaborative governance models become crucial aspects of urban village renovation projects (Chen et al. 2022, Wang et al. 2021).

Research on stakeholder relationships in urban village renovation projects mainly focuses on three aspects. The first one is the status and roles of stakeholders. For instance, The demands and role characteristics of key stakeholders, including the government, developers, and residents, play a decisive role in urban village renovation projects (He et al. 2023, Liu et al. 2021). The second aspect is the stakeholders and their interrelationships, such as the mechanism on interest distribution (Jiang et al. 2020, Zhou et al. 2017, Zhuang et al. 2017), mechanism on conflict resolution (Panahi et al. 2017, Wang et al. 2022), stakeholders' behaviour and game theory (Chu et al. 2020, Guo et al. 2018, Zhu et al. 2022), and collaborative governance models (Li et al. 2022, Liu et al. 2021). Furthermore, there are concerted efforts in exploring and innovating theoretical foundations and research methodology. Zhuang et al. (2019) innovatively combined qualitative and quantitative methods. Liu et al. (2021) expanded the theoretical foundation by integrating stakeholder theory with cooperative theory and symbiosis theory. Zhang et al. (2021) made a transition from individual analysis to network analysis. Current studies have discussed the status and role of stakeholders, their interrelationships, and theoretical approaches in urban village renovation. However, they have overlooked that the urban village renovation project is a dynamic process involving multiple stages, at each of which the composition and importance of stakeholders are different (Aaltonen and Kujala, 2010, Antillon et al. 2018). Moreover, the studies on interaction networks and role positions among stakeholders at various stages during renovation projects are limited. Therefore, it is essential to initiate a comprehensive analysis of stakeholder collaborative relationships and role functional positioning from the perspective of the entire life cycle of the urban village renovation project (Wu et al. 2020, Yu et al. 2019). This approach serves as a necessary prerequisite for a deeper understanding of stakeholders' rights and responsibilities, intending to overcome the dilemma of "governance failure", leverage the advantages of the leading resources, and achieve win-win collaboration among multiple stakeholders.

Based on the preceding analysis, this study employed stakeholder theory and social network analysis to conduct a case study on an urban village renovation project in Tianjin, China. The objectives of this study are to address specific inquiries within the urban village renovation project, such as identifying stakeholders at each project stage, analyzing their interactions, examining variations in roles and functions across stages, and exploring strategies for achieving multi-stakeholder governance.

Literature review

This section consists of four subsections. First, it describes the implementation challenges, international experience, and the main processes of urban village renovation projects. Second, it reviews previous studies on stakeholders and their interrelationships in urban village renovation projects. Next, the application of Social Network Analysis (SNA) methods and their relevance to the research questions in this paper are presented. Last, the gap in previous research is summarized, leading to this paper's content and main contributions.

Urban village renovation and the life cycle of urban village renovation projects. Urban villages represent a typical urban challenge arising from China's rapid urbanization, reflecting the legacy of the urban-rural dual land system (Zeng et al. 2022). Within these urban villages, numerous private residences and commercial facilities have been built to foster the growth of the rental economy, leading to limited urban space expansion and a deviation from regional planning and positioning (Chen et al. 2023). Recognizing the significance of these issues, the Chinese government has issued a series of policies and guidance documents to promote the optimization of urban spatial structure and enhance overall quality. However, due to the complexity of property rights, the diversity of functions, and the plurality of stakeholders, the governance of informal settlements, particularly in urban villages, remains highly complex and challenging (Paula et al. 2023, Wei et al. 2022).

The urbanization trend in countries around the world indicated that even developed countries with 300 years of urbanization experience had been plagued with informal housing issues for more than a century (Chen et al. 2023, Marques, 2016). Urbanization in the United Kingdom underwent a transition from government-led slum clearance movements to a gradual shift towards profit-oriented market operations (Banks and Carpenter, 2017, Becker, 1951). Currently, the UK government incorporates social, economic, and environmental considerations into urban renewal decisions, achieving renewal goals through the coordinated efforts of government, market, and community (Huang and Liu, 2018). Singapore, evolving from a slum in the 1960s to a current global city, offered many successful lessons for other countries to learn from (Li, 2021), such as establishing dedicated urban renewal departments, attracting private funding, emphasizing historical and cultural preservation, and encouraging public participation (Tang, 2023, Yeoh and Huang, 1996). Brazil, as a developing country undergoing urbanization, transformed large-scale demolition into inclusive in-situ upgrading (Annie and Greenlee, 2017, Marques, 2016). Systematic institutional design and refined implementation strategies played a crucial role in Brazil's diverse governance of informal housing (Hong and Chen, 2023, Maria and Alvaro, 2019).

Based on international experience, despite the distinct development context of China's urban village renovation compared to other countries, the core essence revolves around exploring the governance path characterized by pluralistic co-management, inclusiveness, and fairness. Drawing lessons from the urbanization development experience of other countries and exploring a renovation and governance path that aligns with China's urban-

rural dichotomy are key factors for the successful implementation of urban village renovation projects.

The categorization of the life cycle stages in urban renewal projects remains a subject of debate across various research perspectives. For example, to manage the risks in old residential renovation, Huo et al. (2023) divided the project into four stages: decision-making, design, construction, operation, and maintenance. Cui et al. (2021) divided the project cycle into demolition, construction, operation and maintenance, and re-retirement stages to quantify the energy consumption of different retrofit strategies. (Qin and Miao, 2015), studying the development process of public participation in urban village renovation, segmented the project cycle into three stages: pre-establishment, mid-term consultation, and demolition and commencement of construction. The demolition stage stands out as a unique stage in urban village renovation projects, characterized by highly complex interrelationships among stakeholders (Yu et al. 2017). Zhuang et al. (2019) focused on the decision-making stage and categorized it into seven stages: project application, plan development, field survey, etc. Although the names and subdivisions of the project stages varied based on the research questions, the study of South et al. (2018) found that all projects encompassed four stages throughout their life cycle, i.e., project initiation, organizational preparation, project implementation and project completion.

Stakeholders and their interrelationships in urban village renovation projects. Freeman (1984) originally introduced the concept of stakeholders, defining them as "groups without whose support an organization cannot exist". Subsequently, scholars across diverse disciplines, including economics, sociology, and management, expanded and adjusted stakeholder definitions within their respective fields. This led to stakeholders being broadly defined as any group or individual capable of influencing or being influenced by the achievement of organizational goals (Magill et al. 2015, Shah and Guild, 2022, Uribe et al. 2018, Zarghami and Dumrak, 2021).

As an interdisciplinary theory, stakeholder theory has been widely applied in urban village renovation projects, primarily focusing on the analysis of government, enterprises, and residents (Li, 2012, Lin et al. 2022, Liu et al. 2018). For instance, He et al. (2023) explored the role and influence of local governments in a multi-stakeholder context, identifying three types of government involvement: government-led incentive, government-regulated coordination, and government-operated coalition. Du et al. (2022) focused on resident satisfaction and emphasized the importance of "social networks and social protection," "social reciprocity and trust," "social participation and accessibility," and "community cohesion" in enhancing resident satisfaction. Meanwhile, some scholars discovered that social organizations, planners, and news media, while not core stakeholders, also play an essential role in implementing urban village renovation projects (Li et al. 2022, Li et al. 2020, Priemus, 2006).

Different stakeholders exhibit significant differences in their demands (He et al. 2019). Coordinating diverse stakeholder relationships has become a focal point of urban village renovation studies (Liu et al. 2021). Mai et al. (2022) investigated the interactive relationships and their responses to social risks among residents, social organizations, local government, and developers. They found that "residents' needs," "cooperation status," and "level of trust" are crucial for risk management, effectively leveraging China's collectivist culture to reduce social risks. Wu et al. (2020), using the renovation of Putuo District in Shanghai as an example, explored the rights, interests, and knowledge of 42 stakeholders in the project decision-making process to deepen

the comprehensive understanding of stakeholders and construct a decision-making matrix for land redevelopment. Zhou et al. (2022) argued that the collision of value among diverse stakeholders is the catalyst for value conflicts. They established an analysis framework combining Stakeholder Analysis (SA), Social Network Analysis (SNA), and the Theory of Inventive Problem Solving (TRIZ) to identify key value conflicts and stakeholders, thus driving the successful implementation of the projects. Mi (2021) furthermore integrated stakeholders with the theory of collaborative governance, analyzing the influencing factors of stakeholder cooperation in urban village renovation projects under the principles of co-building, co-governance, and sharing.

Social network analysis: an effective method for analyzing stakeholder relationships. Social network analysis (SNA) originated in the 1930s as a quantitative analysis method (Moreno, 1934). Integrating mathematical and computational applications, SNA is utilized to analyze complex interdependencies among various elements and comprehend the characteristics and implications of these relationship structures (Dowding, 1995). As an effective method, SNA has been widely applied in sociology, psychology, economics, and organizational management (Yuan et al. 2021, Zhang et al. 2022).

SNA has significant advantages in the study of stakeholder relationships (Wang et al. 2021). Firstly, SNA depicts the stakeholder relationship network by the interconnections among stakeholders, providing a more intuitive observation of their links and interactions (Lienert et al. 2013). Secondly, SNA situates individual stakeholders within the entire stakeholder network, offering a clear view of the collective characteristics of stakeholders in the relationship network (Leticia et al. 2017). Finally, SNA quantifies the importance of individual stakeholders in the stakeholder network and their key functional roles.

Given the advantages of SNA, using SNA to analyze project stakeholder relationships has become a significant trend in the field of project management (Luo et al. 2023, Wang et al. 2021). For instance, Wang et al. (2020) employed SNA to construct a stakeholder network in BIM-delivered projects, analyzing the characteristics of stakeholder relationships and identifying the core stakeholders in BIM project applications. Zhang et al. (2021) compared and analyzed complex stakeholder behaviour in urban renewal projects in Shenzhen and Chongqing using SNA. According to their analysis results, they proposed corresponding governance strategies, such as optimizing the negotiation platform for urban renewal, increasing multi-stakeholder participation, and implementing policies to regulate participant behaviour. Seyed and Esmail (2023) emphasized the significant role of stakeholder management in lake restoration programs, using SNA to quantify the roles of stakeholders and enhance the management system of lake restoration projects. Clearly, SNA has accumulated extensive research outcomes in the field of project stakeholder relations. It provides a clearer understanding of the roles of various stakeholders in the project, allowing for the leverage of their respective resources advantages to improve project performance(Cook and Gerbasi, 2006; Zhuang et al. 2019).

Stakeholders in urban village renovation projects form a complex organizational structure with social network characteristics (Jin et al. 2023). Using SNA to quantitatively analyze the complex relationships among stakeholders in urban village renovation projects has significant advantages. Therefore, this study intends to employ SNA to analyze the interaction among diverse stakeholders. Consequently, it will offer a clearer understanding of the relationship dynamics among stakeholders in

urban village renovation projects, as well as the individual stakeholder's role and position during the implementation of the renovation.

Research gaps. The present literature has revealed two notable trends. Firstly, research about stakeholders is shifting towards diverse stakeholder participation and collaborative governance (Li et al. 2022). Additionally, characterizing and analyzing stakeholder relationships from a network perspective has become a novel research approach (Jin et al. 2023). However, existing studies have explored the interaction among multiple stakeholders from a static network perspective, lacking in-depth research on the evolution of stakeholder relationships at different stages of urban village renovation projects. Therefore, further identification of research gaps is warranted.

First of all, there is a limited amount of research that adequately considers the relationships among diverse stakeholders in urban village renovation projects. Previous studies indicate that in the new era, urban village renovation projects involve not only core stakeholders such as the government, developers, and the public. Coordinating relationships among diverse stakeholders has become a key factor in the successful implementation of the current urban village renovation projects (Mai et al. 2022). The collaborative governance model is the primary objective for establishing stakeholder cooperation in urban village renovation projects (Mi, 2021; Liu et al. 2021). Therefore, paying attention to the relationship among diverse stakeholders in urban village renovation projects is crucial for their successful execution. Moreover, constructing a stakeholder relationship network from a social network perspective proves to be more effective in quantifying stakeholder relationships than other methods.

Secondly, stakeholder relationships have rarely been explored in stages in previous studies. The urban village renovation projects are characterized by a lengthy project cycle, involvement of diverse stakeholders, and complex interest relationships (Zeng et al. 2022). The composition and significance of stakeholders vary at each stage of the project (Zhuang et al. 2019). However, existing research has rarely considered how stakeholder relationships and their roles evolve across different stages of urban village renovation projects. Therefore, examining stakeholder relationships in urban village renovation projects from a comprehensive life cycle perspective holds practical significance for promoting stakeholder cooperation.

As discussed in the preceding paragraphs, this study conducted a case study on the urban village renovation project in Tianjin, China. Taking a comprehensive life cycle perspective and employing the Social Network Analysis (SNA) method, this paper thoroughly analyzed the evolution characteristics of stakeholder networks and the patterns of role evolution at different stages of the project, thereby addressing the current research gap. This study not only provided an overall understanding of the interactive dynamics among stakeholders across various stages of the urban village renovation project but also provided clearer insights into the position and role of each stakeholder during different stages. Consequently, it opens the black box of stakeholder relations in the urban village renovation project, enabling stakeholders to leverage their resource advantages and enhance the project's governance efficiency.

Materials and methodology
As shown in Fig. 1, this study consisted of four main steps. Initially, stakeholders in the case project were identified and categorized through field research and expert interviews. Subsequently, a questionnaire survey was used to determine the strength of project stakeholders' relationships and formulate a relationship matrix. Following this, the social network analysis method was applied to analyze the overall network characteristics of stakeholders, the group structure characteristics, and the evolutionary patterns of central roles throughout the entire process. Lastly, based on the analysis results, the dilemma issues of collaborative stakeholder governance are identified, and targeted countermeasures are proposed.

Methods. This study utilized a mixed research approach, combining a single case study and social network analysis. On the one hand, single-case studies are inclined to distort behavioural patterns from complex phenomena, providing an opportunity to deepen the understanding of such phenomena, especially in multi-stage longitudinal studies (Eisenhardt and Graebner, 2007). Through the single case study method, this research tracked and observed the behavioural changes of stakeholders at each stage, capturing the characteristics of the stakeholder relationships at each stage and elaborating on their behaviours with primary data. On the other hand, social network analysis is a quantitative research method that combines graphical and mathematical models to analyze the positions and interrelationships of social members in a network (Koene, 1984). Exploring stakeholder interaction at each stage of the urban village renovation project from the social network perspective allows for a more comprehensive and objective portrayal of overall structural characteristics, group evolution characteristics, and node function evolution law in each stage (Mok et al. 2017). In conclusion, the mixed research method combining a single case study and social network analysis is well-suited for studying stakeholder relationships in urban village renovation projects. Leveraging the advantages and characteristics of each method, it contributes to a deeper understanding of stakeholder interactions and role characteristics.

This study used UCINET 6.0 to analyze the stakeholder network of the urban village renovation project and employed NETDRAW software to create the relationship diagram. To improve stakeholder collaboration, analyzing stakeholder relationships in urban village renovation projects involves examining the overall structure, group characteristics, and participant status. Network density and average node distance are commonly used indicators to evaluate the overall network characteristics of stakeholder networks (Liu, 2009). To further explore the interactions between stakeholders, core-periphery and small clique analyses were selected to investigate stakeholder groups in this study. Through core-periphery and clique analyses, it is possible to identify core stakeholders at each project stage and determine which stakeholder relationships are more closely related (Liu Fang, 2015). In addition, the authors applied three frequently used centrality measures to analyze the stakeholder network, including degree centrality, betweenness centrality, and closeness centrality (Wei et al. 2022). Centrality analysis provides a clearer understanding of the roles and major contributions of stakeholders in the urban village renovation process. Detailed descriptions and formulas for each indicator are tabulated in Table 1.

Study area. This study selected an urban village renovation project in Beichen District, Tianjin, China (refer to Fig. 2 for the location map). Before the renovation, the area primarily consisted of bungalows with dilapidated houses, outdated infrastructure, lagging surrounding facilities, and inadequate road construction. Security issues, as well as hygiene and fire hazards, were prevalent (see Fig. 3 for pictures before renovation). The government launched the project in 2005 to improve the living environment
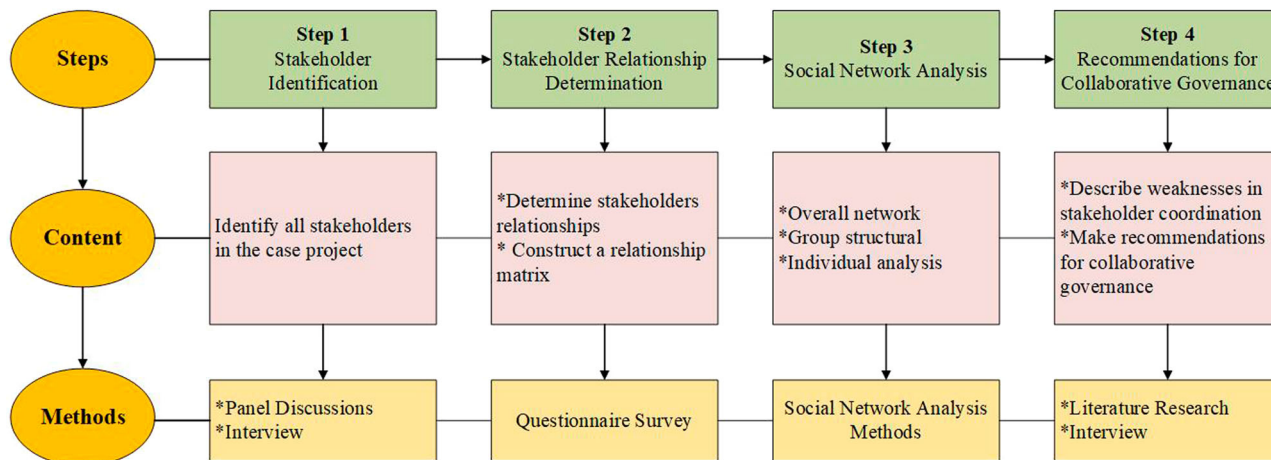
Fig. 1 Research process.

Table 1 Indicators for social network analysis.

SNA indicators	Indicator description	Formulas
Network Density	Network density is the ratio of connections between network nodes to the maximum number of links in the entire network. The network density measures how closely the nodes are connected.	$D = \frac{2m}{n(n-1)}$ Where: D is network density; m is the sum of the number of connections in the relational network; n is the number of actors.
Average Distance	The average distance is the mean value of the optimal path among all nodes and indicates the efficiency of information transfer. The smaller the indicator's worth, the better the accessibility of the network.	$L = 2\frac{\sum_{i \neq j} dij}{n(n-1)}$ Where: L is the average distance; d_{ij} is the shortest path length between i and j; n is the number of actors.
Core-Periphery	Based on the closeness between different nodes in the social network, the nodes can be divided into core and periphery zones. Nodes in the core occupy a more important position in the overall social network.	
Small Cliques	Cliques, also called cohesive subgroups, are analyzed as collections of well-connected actors in a network. It divides the small groups formed within the network with strong ties, which helps to reveal the substructure situation within the network.	
Degree Centrality	Degree Centrality is the ability to communicate and interact directly with other stakeholders—the greater the degree of centrality, the higher the position in the relationship network and the greater the power.	$C_{RDi} = \frac{\sum_{j=1}^{n} xij}{n-1}$ Where: C_{RDi} is degree centrality; x_{ij} is either 0 or 1. If i and j are connected, x_{ij} is 1. Otherwise, it is 0; n is the number of actors.
Betweenness Centrality	Betweenness centrality represents the spacing between stakeholders—the higher the betweenness centrality, the greater its ability to control resources.	$C_{RBi} = \frac{2\sum_{j<k} \frac{gjk(i)}{gjk}}{(n-1)(n-2)}$ Where: C_{RBi} is betweenness centrality; $g_{jk}(i)$ is the number of shortest paths where nodes j and k are connected and pass through node i; g_{ik} is the number of shortest paths where j and k are connected; n is the number of actors.
Closeness Centrality	Closeness centrality represents the sum of each stakeholder's distance from other stakeholders. The smaller the closeness centrality, the lower its dependence and the higher its independence.	$C_{RPi} = \frac{n-1}{\sum_{j \in N} dij}$ Where: C_{RPi} is closeness centrality, d_{ij} is the shortest path length between i and j; n is the number of actors.

for residents. However, due to the difficulties in negotiation regarding the demolition and relocation, the demolition and relocation work of the project gradually commenced only in 2015. The first batch of villagers successfully relocated back to their homes in 2021. Currently, more than 3,900 housing units have been completed, with 1307 units under construction. It is expected that the villagers will move in by early 2024. Figure 4 illustrates the overall layout after the completion of the project, showing a significant improvement in residents' living environment. Based on the construction focus of the project and the characteristics of stakeholder stages, the project was divided into four stages: Preliminary Preparation stage (PP), Demolition and

Relocation Compensation stage (DC), Development, Construction and Implementation stage (CI), and Post-Maintenance and Operation stage (MO).

The main reasons for selecting this case are as follows. (1) Representative development mode: The project adopts a mode characterized by government-led, village-enterprise collaboration and market-oriented operation. The government implements the urban village renovation project, with the construction unit responsible for demolition and relocation work and compensating the villagers. Currently, this development mode is widely applied in urban village renovation projects across most Chinese cities. (2) Complexity of stakeholder relationships: The project

Fig. 2 Location map of Tianjin Beichen District urban village renovation.

Fig. 3 Pictures of the project before renovation.

Fig. 4 Pictures of the project after renovation.

includes stakeholders at various government levels, developers, villagers, constructors, and other stakeholders with complex relationships. (3) Data accessibility: Due to geographic and relational advantages, the authors have been tracking this urban village renovation project since 2014, gaining information on the project's progress and key details. Multiple in-depth interviews were conducted with stakeholders such as government officials, developers, and villagers, accumulating a large amount of material information for this case study. (4) Project lifecycle completeness: The renovation project went through the entire lifecycle from initiation to maintenance and operation, meeting the requirements for a comprehensive lifecycle analysis of the project.

Construction of stakeholder network in urban village renovation project. The stakeholder network consists of nodes (stakeholders) and connections (relationship strength between stakeholders). Therefore, to construct the stakeholder network in the urban village renovation project, it is essential to first identify the stakeholders in the case project. Subsequently, a stakeholder matrix was constructed based on the relationships between stakeholders to facilitate the subsequent analysis of network metrics.

Stakeholders identification. This study employed a combined approach of literature review and focus group interviews to identify stakeholders in urban village renovation projects. This approach ensured both the reliability of stakeholder identification and the enhanced practical relevance of the research outcomes. First of all, stakeholders in the urban village renovation project were systematically categorized through an in-depth literature review, summarizing the primary functions associated with each stakeholder. Subsequently, a group discussion was conducted with six individuals actively involved in the case project, including two government officials from the project's district, the project manager from the developer, the project manager from the constructor, the manager from the design unit, and the manager from the consultant. Through this collaborative discussion, 11 stakeholders were identified and established as the initial stakeholder list. During the subsequent field research, based on the results obtained from semi-structured interviews with various project participants, two additional stakeholders, i.e. news media and the property management unit, were incorporated into the original list. Consequently, a final list of 13 stakeholders was established, with stakeholders systematically staged according to the practical conditions of the renovation (refer to Table 2).

Establishment of stakeholder relationship matrix. The questionnaire was designed to determine the strength of stakeholder relationships. The respondents were selected based on two criteria: (1) they represented one of the 13 stakeholders listed; (2) they had experience participating in urban village renovation projects. Before designing the questionnaire, the method for measuring relationship strength was determined in the first place. Due to the significant roles of rights and interests in stakeholder relationships in urban village renovation (Zhuang et al. 2019), this study used "the existence of contractual relationships," "the existence of subordinate relationships or mutual interests," and "the existence of communication opportunities" as the criteria to measure relationship strength, assigning "5," "3," and "1," respectively. If none of the above relationships exist, a value of "0" is assigned. The questionnaire consisted of two main parts. The first part contains background information about the respondents filling out the questionnaire. The second part measures and scores the strength of the relationship between the stakeholders.

Questionnaires were distributed both online and offline to project stakeholders in four different periods: June to July 2014, September to

Table 2 List of stakeholders in each stage of the urban village renovation project.

No.	Stakeholder	Description	Stage			
			PP	DC	CI	MO
1	Government(G)	Decide whether to initiate a project and supervise its implementation.	√	√	√	√
2	Construction Management Unit(CM)	Approval management departments related to engineering and construction projects	√	√	√	
3	Land Consolidation and acquisition unit(LCA)	Integrate the management of geographically dispersed land parcels and be responsible for demolition, expropriation, compensation and resettlement, and other related work.		√		
4	Construction unit(CU)	The general contractor for remodeling projects	√	√	√	√
5	Constructor(C)	Responsible for project site construction and management			√	
6	Consulting Service Unit(CS)	Include design units, bidding agents, engineering consulting units, supervisors, and investigations.	√		√	
7	Supplier(S)	Supply materials during the construction of the project			√	
8	Financial institution(F)	Provision of funds and loans to other stakeholders, such as banks and trusts		√	√	
9	Legal institution(L)	Legal advisory services for project disputes		√		
10	Community Council (CC)	Coordinate relationships between government, businesses and residents.	√	√		√
11	Property Management Unit(PM)	Responsible for the daily operation and management of the project				√
12	Public(P)	Former property owners, tenants, and residents in the vicinity of the project	√	√	√	√
13	Media(M)	Provide exposure channel for project implementation	√	√	√	√

* "√" indicates the stakeholders involved in this stage.

October 2016, June to July 2018, and September to October 2021. These four time periods corresponded to different stages of project development. In 2014, 153 questionnaires were distributed, and 142 valid questionnaires were collected. In 2016, 136 questionnaires were distributed, and 130 valid questionnaires were collected. In 2018, 143 questionnaires were distributed, and 136 valid questionnaires were collected. In 2021, 162 questionnaires were distributed, and 152 valid questionnaires were collected. In total, 560 valid questionnaires were collected across the four periods, with a response rate of over 94%. Good reliability and consistency of all collected questionnaires were verified. Finally, this study constructed a four-stage "Stakeholder-Stakeholder" adjacency matrix based on the relationship strength data obtained from the questionnaires. The four-stage "Stakeholder-Stakeholder" adjacency matrix can be found in Supplementary Table S1, Supplementary Table S2, Supplementary Table S3, and Supplementary Table S4 online.

Network characteristics and analysis

Network structure. The interaction network among different stakeholders at different stages is shown in Fig. 5, providing a visual presentation of stakeholder interactions during each stage. The nodes in the diagram represent stakeholders, and the connecting lines define the relationships between them. Based on the relation network diagram, this study further measured indicators such as network density and average distance to describe the evolution of the stakeholder relationship network in the project, which are tabulated in Table 3.

In the preliminary preparation stage (PP stage), the network density is the highest, and the average distance between nodes is the lowest, indicating a close connection among stakeholders in this stage, with efficient information transmission. This is because the government is responsible for coordinating relevant functional units, handling approval procedures such as reporting and project approval, organizing experts for feasibility consultations, identifying cooperation partners, and conducting in-depth public appeals and other preparatory work. In the demolition and resettlement compensation stage (DC stage), the network density is the lowest, and the average distance between nodes is the highest. This is because stakeholders such as financial institutions and legal institutions, although entering the relationship network at this stage, have low connectivity with other stakeholders. During the development, construction, and

implementation stage (CI stage), the network density slightly increases compared to the previous stage but remains at a relatively low level, showing that the connections among various stakeholders are not very close. These results indicated that the constructor carried out the main work in this stage. Although stakeholders such as the government, construction management unit, and the public are involved in the CI stage, they mostly play a supervisory role with limited interactions among themselves. The overall network had a "center-periphery" characteristic. In the post-maintenance and operation stage (MO stage), the network connections are simpler, but the network density is higher. This indicated close connections among stakeholders in this stage. The comprehensive network had an "overall coordinated" characteristic.

Overall, the degree of collaboration in the stakeholder relation network showed a "U"-shaped trend, while the efficiency of information transmission showed an inverted "U"-shaped trend. In the PP and MO stages, there were relatively fewer stakeholders, but the connections were tight, resulting in fast information transmission efficiency. In contrast, the intermediate two stages involve a higher number of stakeholders, but the degree of closeness significantly decreases, leading to lower information transmission efficiency.

The evolution characteristics of each project stage in this study are attributed to the following reasons: (1) In PP stage, the government holds significant discourse power and has strong coordination capabilities. It can effectively and efficiently collaborate with other stakeholders to jointly complete the pre-project feasibility study. Additionally, each stakeholder shows a strong willingness to participate due to their interests. (2) The major conflict during the DC stage lies in coordinating the interests between the government and the public. Stakeholders face trust issues and information asymmetry due to disputes over interests. (3) The stakeholders in the CI stage are highly specialized, with clear divisions of labor. However, their business activities are singular, and opportunities for interaction are limited, leading to information barrier challenges. (4) During the MO stage, the formal contractual relationship between the property management unit and the public plays a crucial role in establishing strong connections.

Group structure characteristics

Stakeholder "core-periphery" analysis. The previous section analyzed the collaborative network characteristics and evolution
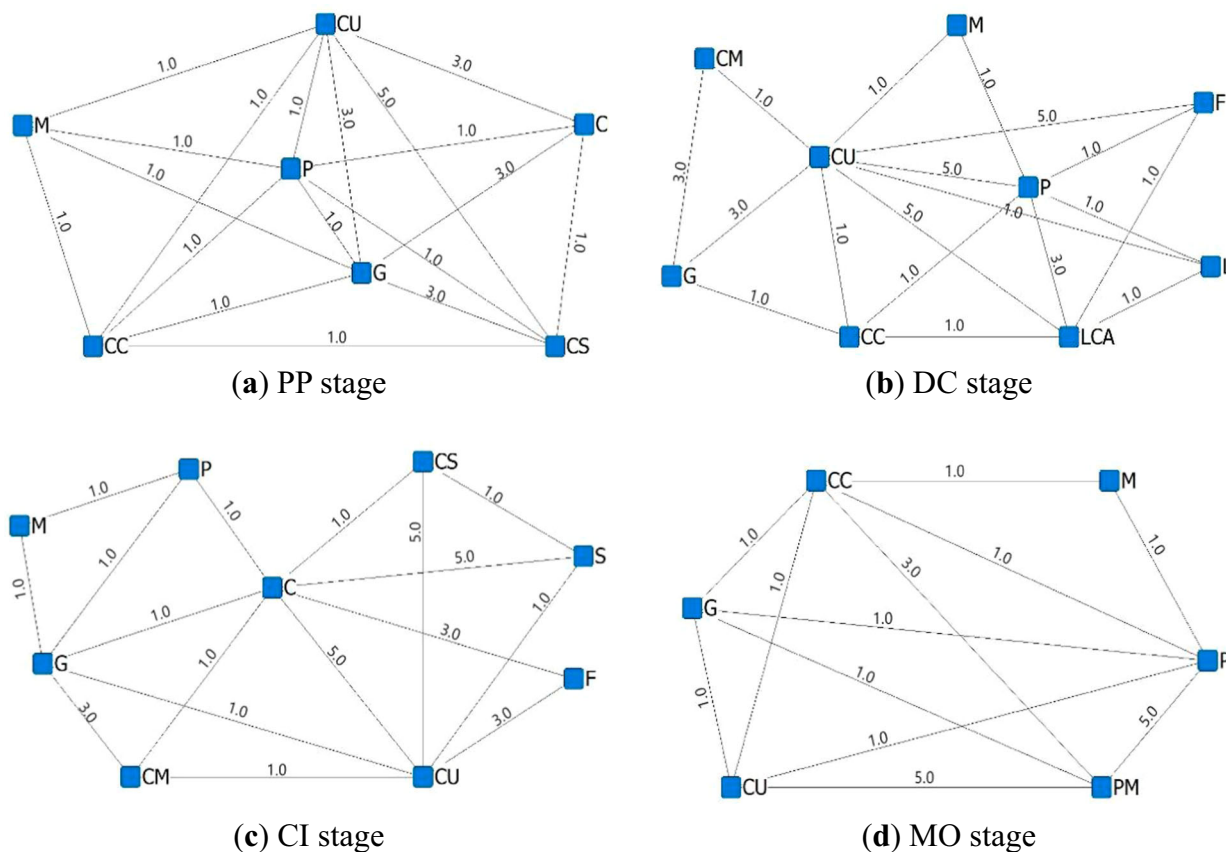
Fig. 5 Collaborative network diagram of stakeholders at different urban village renovation project stages. a Collaborative network diagram in the PP stage; **b** Collaborative network diagram in the DC stage; **c** Collaborative network diagram in the CI stage; **d** Collaborative network diagram in the MO stage.

Table 3 Characteristics of collaborative network structure of stakeholders in urban village renovation projects.

Index	Stage			
	PP	DC	CI	MO
Network scale	7	9	9	6
Network density	0.857	0.472	0.500	0.800
Average distance	1.143	1.583	1.556	1.200
Network characteristics	Overall coordination	Core periphery	Core periphery	Overall coordination

patterns of each stage from the perspective of the overall network. Nevertheless, it was difficult to precisely identify the "core-periphery" stakeholders in different stages. Therefore, this study used UCINET software to analyze the "core-periphery" structure of the collaborative network in each stage of the urban village renovation project. Stakeholders were classified into two categories based on the mean value of the core degree as the delineation criterion: core stakeholders and peripheral stakeholders. The analysis results are shown in Table 4.

Generally, the core stakeholders in the relation network of the urban village renovation project have been changing across different stages. The core stakeholders in the collaborative network in the PP stage were the government, consulting service units and construction units, engaging in in-depth discussions on issues such as the feasibility study and design planning of the urban renovation project. In the DC stage, the core stakeholders in the collaborative network were the construction units, the public, and the land consolidation and acquisition units, mainly coordinating matters related to demolition, resettlement, and compensation between the government and the public. The core

stakeholders in the collaborative network in the CI stage were the constructors, construction units, and consulting services, with construction becoming the primary goal of this stage. During the MO stage, property management units and the public became the core stakeholders in the collaborative network.

Small clique analysis. The clique phenomenon can not only affect the relationship changes within the clique but often has some driving or inhibiting effects on the overall structure of the collaborative network (Liu Fang, 2015). Therefore, in this study, the UCINET software's iterative correlation convergence algorithm (CONCOR) function was used to analyze the clique phenomena existing in each stage of the urban village renovation project. Figure 6 shows the cohesive subgroup diagram in each stage of the urban village renovation project. This paper calculated the density matrix for each stage of cliques to provide a more in-depth analysis of the relationships within and between small cliques. The network density at each stage was used as the threshold value to obtain the binary matrix. If it is greater than the overall network density, the value is set to 1, indicating a close

Table 4 Stakeholder relation network core-periphery analysis.

Stage	Core Stakeholders	Peripheral Stakeholders
PP	Government (0.64)	Construction Management Unit (0.32)
	Consulting Service Unit (0.50)	Public (0.16)
		Community Council (0.14)
	Construction unit (0.43)	Media (0.10)
DC	Construction unit (0.87)	Financial institution (0.21)
		Government (0.14)
	Public (0.28)	Community Council (0.07)
		Legal institution (0.07)
	Land consolidation and acquisition unit (0.28)	Construction Management Unit (0.06)
		Media (0.01)
CI	Constructor (0.61)	Supplier (0.28)
		Financial institution (0.26)
	Construction unit (0.61)	Government (0.13)
		Construction Management Unit (0.11)
	Consulting Service Unit (0.29)	Public (0.05)
		Media (0.01)
MO	Property Management Unit (0.89)	Construction unit (0.29)
		Community Council (0.24)
	Public (0.42)	Government (0.10)
		Media (0.06)

Table 5 The small cliques binary matrix at each stage of the urban village renovation project.

PP Stage	C1	C2	C3	DC Stage	C1	C2	C3	C4
C1	1	1	1	C1	1	1	0	0
C2	1	1	0	C2	1	1	1	0
C3	1	0	1	C3	0	1	1	1
				C4	0	0	1	0

CI Stage	G	C1	C2	C3	MO Stage	C1	C2	Media
G	-	1	0	1	C1	1	1	0
C1	1	1	1	0	C2	1	1	1
C2	0	1	0	0	Media	0	1	-
C3	1	0	0	1				

* "G" is an abbreviation for the government.

connection. If it is less than the overall network density, the value is set to 0, indicating loose connections within or between small cliques. The specific results are shown in Table 5.

According to the small cliques diagram (Fig. 6) and the small cliques binary matrix (Table 5), there were three small cliques in the PP stage. C1 included the government, construction unit, and the public; C2 included the construction management unit and consulting service unit; and C3 included the community committee and the media. C1, driven by the core roles of the government and construction unit, has close ties with C2 and C3, while the connections between C2 and C3 are relatively sparse. During the DC stage, a new small clique C1 was formed by construction management units, such as the Planning Bureau and the Environmental Protection Bureau, acting as a separate entity and not directly connecting with other stakeholders. This indicates that during this stage, the government had assigned the expropriation and compensation affairs to construction

management units. The frequency of information exchange among small cliques was low compared to the previous stage. In the CI stage, the government did not form an alliance, while stakeholders within C2 had relatively loose connections. However, the C1 and C2 cliques were exceptionally closely related. Meanwhile, C3 had little contact with other small cliques, leading to apparent clique fragmentation. The MO stage consisted of three small cliques. The media, as an independent clique, had less frequent connections with other stakeholders during this stage. Stakeholders within C1 and C2, as well as the connections between the two small cliques, had a high level of closeness.

Small cliques exist in the collaborative network in all stages of urban village renovation projects. During the PP and MO stages, there was a high degree of internal and inter-clique connectivity, while in the two intermediate stages, there was a noticeable phenomenon of information isolation and mutual fragmentation among small cliques. The core stakeholders, with their resource-driving advantage, form small cliques, showing significantly higher frequencies of internal and inter-clique connections compared to small cliques composed of peripheral stakeholders.

Individual role evolution. In the previous section, the "corer-periphery" structure confirmed the differences in the importance of stakeholders at various stages in the urban village renovation project. However, what differences exist in the roles and functions of the same stakeholders in different stages? Therefore, this paper selected stakeholders involved in the entire process as the research subjects: government, construction unit, the public, and the media. The evolutionary changes in the roles and functions of these four stakeholders at different stages were analyzed and presented in Fig. 7. Due to variations in the number of stakeholders in each stage, the centralities were normalized before the analysis. The degree centrality can be found as Supplementary Table S5 online. The betweenness centrality can be found as Supplementary Table S6 online. The closeness centrality can be found as Supplementary Table S7 online.

The government had the highest degree centrality and betweenness centrality in the PP stage, indicating that it had the most direct connections with other stakeholders. Its interaction ability and control over resources were the strongest, establishing a prominent position and wielding significant power in the collaborative network. In the DC stage, the degree centrality and betweenness centrality of the government significantly decreased, while those of construction units rose to the highest level. This shift indicated that during this stage, the construction unit replaced the government in taking on the primary coordination and organizational responsibilities. The degree centrality of construction units during the CI stage remained much higher than that of the government, but the betweenness centrality was only slightly higher. This suggested that in this stage, there was no significant difference in the resource control capabilities between the construction units and the government. Combining these with the analysis results from the "core-periphery " structure in Table 4, it is clear that the construction units play a more crucial role in this stage. In the MO stage, the degree centrality and betweenness centrality of the construction unit and the government decreased. The property management unit and the public assumed central positions in this stage, while the construction unit and the government were mainly responsible for the post-project operational and maintenance supervision and resident satisfaction survey. The degree centrality and betweenness centrality of the public in the entire renovation project process exhibited an "N"-shaped trend, with the lowest points at the DC stages. Associated with analyzing small cliques in this stage, the public mainly consisted of

(a) PP stage

(b) DC stage

(c) CI stage

(d) MO stage
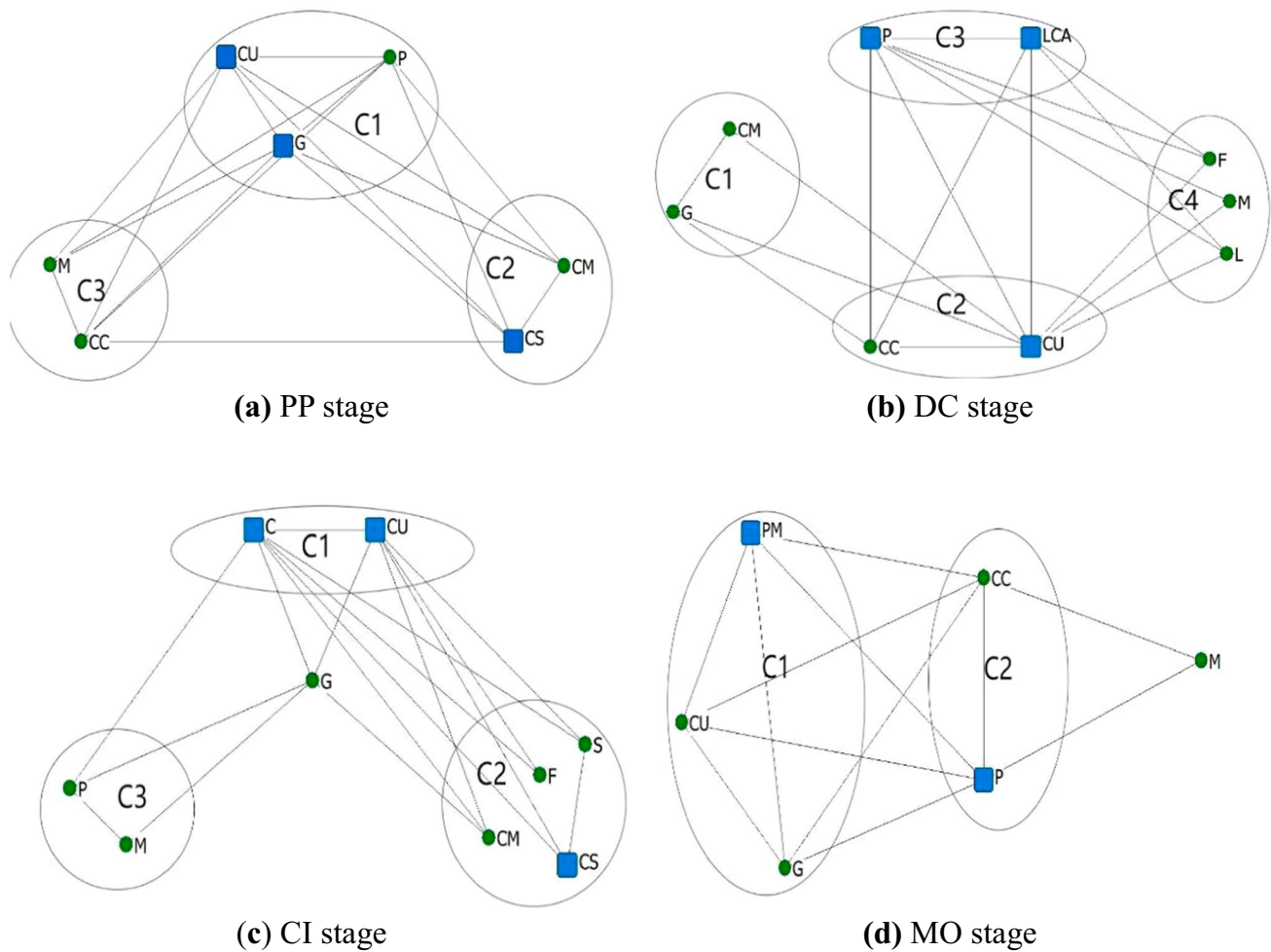
Fig. 6 The small cliques in the relation network at all project stages (Cn stands for small clique situation). Legend Description: ▪ Core Stakeholders, ● Peripheral Stakeholders. **a** Small clique situation in the PP stage; **b** Small clique situation in the DC stage; **c** Small clique situation in the CI stage; **d** Small clique situation in the MO stage.

surrounding residents, together with the media forming a small clique, which limited interactions with other stakeholders. In the MO stage, the degree centrality and betweenness centrality of the public reached the highest level, indicating that the public had the most direct connections with other stakeholders during this stage, demonstrating strong interactive capabilities and resource control. The closeness centrality of the media maintained at the lowest level throughout the entire project, which suggested the media in the collaborative network was less influenced by other stakeholders and exhibited a high degree of independence.

The preceding discussions indicated that there were differences in the functions of different stakeholders within the same stage, and the roles of the same stakeholder also vary across different stages. Throughout the entire lifecycle of the project, the government underwent a transformation from a "leader" to a "coordinator." The public transitioned from a "passive recipient" to an "active participant." Construction units had strong control over resources, assuming the role of a "resource controller." Although the media operates as peripheral stakeholders, its high independence allows it to supervise project implementation effectively, with the attributes of an "edge supervisor."

Results discussion and suggestions
The published literature finds that the success of urban village renovation projects is closely related to stakeholder coordination (Chen et al. 2022; Jiang et al. 2020). In addition, there are

differences in the composition and importance of stakeholders at various stages of urban village renovation projects (Antillon et al. 2018; Zhang, 2022). Therefore, this study provides an in-depth analysis of stakeholder relationships in urban village renovation projects from an entire lifecycle perspective based on the Social Network Analysis (SNA) method. According to the social network analysis results from the previous section, this section provides a detailed discussion of the weakness in stakeholder collaboration and offers recommendations to enhance stakeholder cooperation in Chinese urban village renovation projects.

Results discussion: the weaknesses of stakeholder collaborative relationships
The connectivity of the stakeholder network at the DC stage needs to be improved. There was limited interaction among stakeholders in the DC stages, and the overall network density was at a relatively low level, indicating a weak network structure. The reasons for the weak connectivity among stakeholders in this stage are multifaceted. Firstly, stakeholders such as the government, construction units, and demolished villagers have diverse interests, leading to potential conflicts and divergences with a lack of effective communication and coordination mechanisms, resulting in weak connections among them. Secondly, the government and construction units often hold more information and power, while the public, as a disadvantaged group, has relatively limited
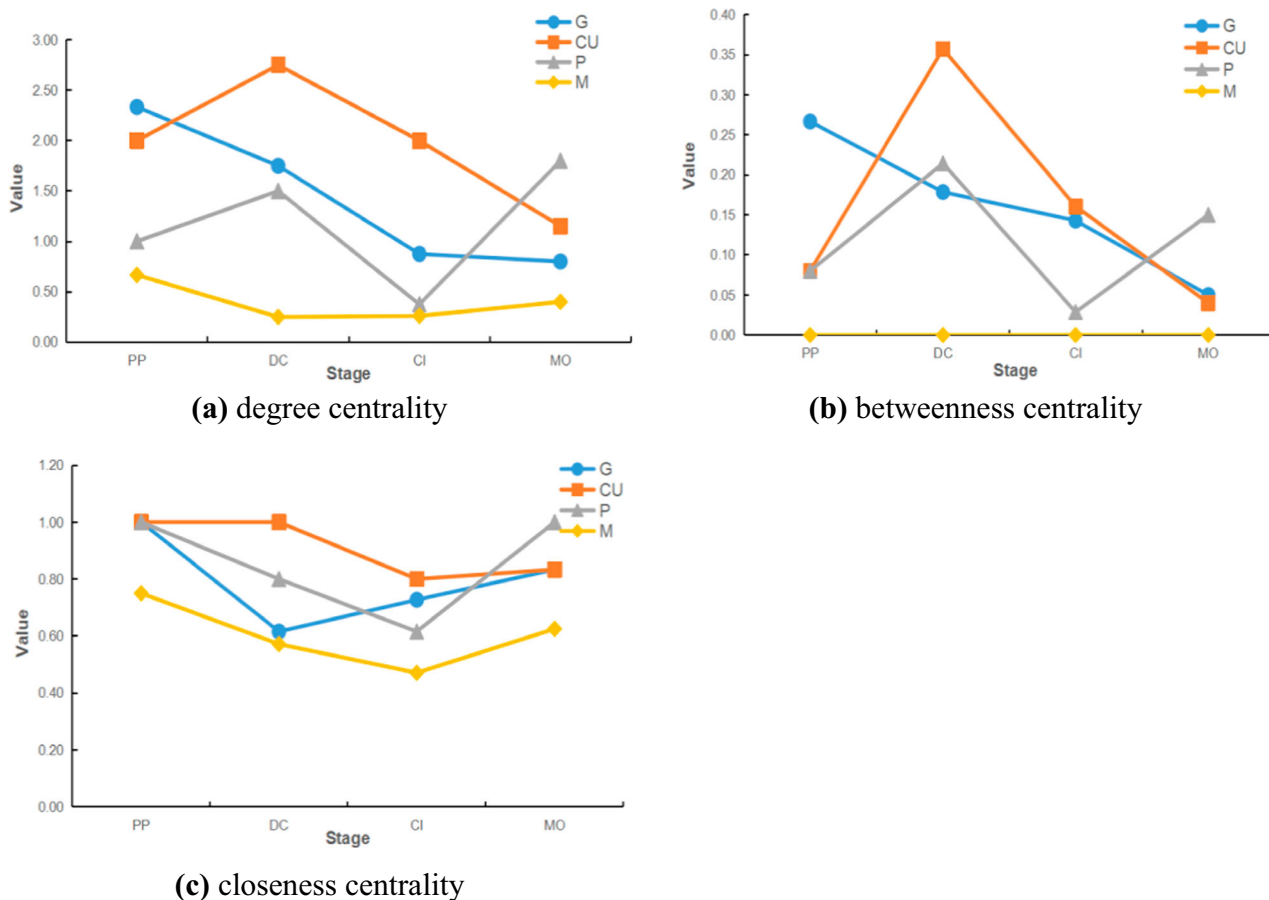
Fig. 7 The evolution diagram of the centrality of stakeholders at each stage of the urban village renovation project. Legend Description: ● Government, ■ Construction unit, ▲ Public, ◆ Media. **a** Trend figure of degree centrality change; **b** Trend figure of betweenness centrality change; **c** Trend figure of closeness centrality change.

information. Hence, a predicament of information asymmetry and a lack of trust are created, leading to weakened connectivity.

Especially since the public, as a vulnerable group, has relatively limited information. Finally, this stage primarily involves a continuous negotiation process between construction units and displaced residents to seek a relatively balanced outcome. While financial institutions, legal institutions, and the media are stakeholders in this stage, they mainly serve supportive and supervisory roles, with limited opportunities for interaction with other stakeholders, contributing to weak network connectivity.

Small clique fragmentation is a significant difficulty in the CI stage. The phenomena of small cliques were present in the relationship networks in all stages of the renovation project. During the CI stages, there was a noticeable fragmentation among small cliques. This stage comprised four sub-cliques, with the government not forming an alliance. There was more frequent communication between C1 (construction units and constructor) and C2 (construction management units, consulting services units, suppliers, and financial institutions). In contrast, the communication frequency between C3 (the public and the media) and the other small cliques was significantly lower, with distinct fragmentation. Based on the analysis results, it is clear that the main task at this stage was construction. Thus, there was higher communication frequency among stakeholders related to on-site construction, such as construction units, constructors, and consulting service units. Oppositely, the external parties to on-site construction, such as the public and the media, were less connected to other stakeholders, showing a clear state of fragmentation.

The importance of the public in the PP stage is under-explored. Public participation has consistently been a hot issue in urban village renovation projects under people-oriented and livelihood-oriented construction goals. The network analysis results revealed high public participation in the DC and MO stages and low public participation in the PP and CI stages. In addition, empirical findings from field research and expert interviews revealed that understanding the public's needs and incorporating them into the early decision-making system in the PP stage could help mitigate disputes among stakeholders in the later stages. There are two main reasons for the low level of public participation in the PP stage. Firstly, there are shortcomings in the public participation process, including insufficient effectiveness of information disclosure mechanism and policy promotion, imperfection of information feedback mechanism, and non-implementation of the feedback loop of public opinions. Secondly, the public's willingness and capacity to participate are hindered and influenced by their comprehension of policies, available free time and physical health, negotiation and decision-making abilities, and proficiency in professional knowledge.

Recommendations to promote stakeholders' collaboration
Fully consider villager needs and flexibly transform development mode. In the past, the renovation of urban villages was usually carried out through land expropriation, transforming rural collective land into state-owned land for renovation. However, some villagers developed strong resistance due to factors such as unwillingness to change lifestyle habits and inadequate

compensation amount, resulting in a "nailed-down" dilemma and generating huge time costs and economic pressure. Nowadays, with the continuous exploration of urban village renovation projects, the Chinese government has introduced a series of policies related to residential land use and collective-operated construction land. Without expropriation or forced demolition, these policies can still improve the living environment of urban villages. Therefore, during the PP stage of the renovation, the government should conduct a comprehensive investigation and interviews with villagers to understand their willingness to renovate. This enables the identification of more adaptable development patterns and effectively circumvents the effects of structural mismatches. Compared to rigid governance methods, this consultative approach can fundamentally solve the resistance to demolition and relocation and effectively shorten the time cycle of urban village renovation projects.

Facilitate two-way communication channels to ensure public participation. The public is the stakeholder and the ultimate beneficiary of the urban village renovation project. However, at the PP stage, public participation is primarily organized by village collectives, involving consultation and decision-making, where the public can only passively receive information about the renovation without influencing decisions in return. To address the low level of public participation, especially at the PP stage, the promotion by the government and the media should be increased first, clearly outlining the expected benefits of participation. This helps the public recognize the convenience in their lives after the renovation project, thereby enhancing their willingness to participate. Secondly, organizing the dissemination of professional knowledge and providing training can improve the public's understanding of policies and the entire process of innovation projects, fostering their participation capabilities. Finally, improving public participation procedures can ensure effective public participation. The government should establish diverse channels for public participation, refine the procedures, and effectively obtain feedback from public opinions. Village collectives should act as liaisons between the government and the villagers, facilitating the connection between policy distribution and opinion feedback. By cultivating public awareness and capabilities in participation and facilitating two-way communication channels, the public can genuinely influence the entire decision-making process of the renovation project.

Utilize the resource-driven advantages of core stakeholders. In the urban village renovation project, the government should fully mobilize the enthusiasm of all stakeholders. As a strategy planner, the government has advantages in the governance of stakeholder relations with a high position and far-sighted perspective. In the new era of urban village renovation projects, the government should grasp the strategic direction of the project renovation and coordinate the interests of multiple stakeholders. As a market entity, the construction unit has a keen vision and flexible characteristics. In the process of implementing renovation, the effective allocation of resources and collaboration among stakeholders is inseparable from the consultation and exchange of construction units. In the new era of urban village renovation projects, the emphasis extends beyond the decisive role of the construction unit in allocating resources to a heightened focus on sustainable development. The future approach should break away from the traditional real estate development model of "one-time transactions" and instead integrate urban village renovation with guaranteed rental housing. This approach not only enhances residents' living environment but also ensures the long-term operational sustainability of construction units.

Establish an online sharing platform to break the clique fragmentation dilemma. Strengthening informatization and network construction is essential to enhance stakeholders' governance efficiency in the new situation. Establishing an interactive sharing platform could effectively integrate information resources among various stakeholders, such as the government, construction units, constructors, and the public. This breaks down communication barriers and addresses the fragmentation of governance systems, ensuring the realization of collaborative governance among multiple stakeholders in urban village renovation projects. Particularly during the CI stage, on-site construction is mainly carried out by core stakeholders with solid professionalism, such as construction units, constructors, and consulting services, with limited involvement from marginal stakeholders like villagers and the media. Establishing online sharing platforms could increase communication frequency among stakeholders and effectively alleviate the clique fragmentation phenomenon during this stage.

Conclusion
To leverage their respective resource advantages and achieve effective collaboration, stakeholders aim to implement collaborative governance in urban village renovation projects. This goal is pursued due to the complexity of stakeholder relationships in such projects and the variations in the composition and significance of stakeholders at different stages of project construction. Therefore, this study utilized a mixed research method, combining a single case study and social network analysis, to investigate the dynamics in stakeholder relationship networks during the construction of an urban village renovation project in Tianjin, China. By analyzing the evolution of stakeholder relationships, the study uncovered the challenges associated with achieving stakeholder collaboration. The findings revealed that the main constraints to achieving collaboration among stakeholders in the urban village renovation project were the limited public participation in the PP stage, the weak connections in the DC stage, and the apparent clique fragmentation in stakeholder networks during the CI stage.

How do we achieve the goal of collaborative governance among stakeholders? Firstly, it is essential to thoroughly understand the residents' needs and align the development mode with their actual requirements. Secondly, increasing public participation in the PP stage is crucial. This could effectively minimize the negative impact of public dissatisfaction in the later stages and enhance overall public satisfaction with the project. Thirdly, the core stakeholders should leverage their resource-driven advantage and incorporate more stakeholders into the collaboration network. Finally, establishing a network-sharing platform proves to be an effective measure to overcome small clique fragmentation.

Although this study specifically focused on the urban village renovation in Tianjin, China, its theoretical, methodological, and practical implications extend beyond this context and could be applicable to other cities and countries. Firstly, from a theoretical perspective, the constructed theoretical knowledge system that combines stakeholder analysis with synergistic governance goals provides a clearer goal orientation for stakeholder research in urban villages. Secondly, in terms of methodology, the adoption of a mixed research method, combining a single case study with social network analysis, acknowledges the complementary nature of qualitative data and quantitative networks. This approach aids in gaining a more in-depth understanding of stakeholder interactions and role characteristics. The mixed qualitative and quantitative research methodological framework proves advantageous in stakeholder relations research and can be continued in future studies. Finally, in terms of practical significance, this study conducts a comprehensive examination of stakeholder relations throughout the entire lifecycle, aligning more closely with the current practices in implementing urban village renovation

projects. The results of the analysis could help stakeholders, including the government, developers, the public, and the media, better understand their roles and critical strengths in the various stages of urban village redevelopment, thus enhancing decision-making efficiency and effectiveness.

At present, the renovation method of urban villages in the Beichen District of Tianjin is a typical model in China's urban village renovation projects, and the research findings hold significant reference value. In addition, the stakeholder analysis model constructed in this study, from an entire lifecycle perspective, enables a more profound exploration of stakeholder interrelationships and is equally applicable in other project stakeholder studies. Future research could be further developed in the following areas: (1) The measurement of stakeholder relations could be improved. This study identified measures of "5", "3", "1," and "0" mainly from the perspective of power and interests, where the actual stakeholder relationships are more complex. Future research could adopt a more comprehensive approach by assigning values to interaction intensity, communication frequency, and cooperation frequency. (2) A comparative study of stakeholder relations under different development modes could be conducted. This study found that differences in the development models, including government-led, government-enterprise cooperative, and village collective self-initiated, would lead to significant differences in stakeholder relationships. Future research could explore the variability of stakeholder relationships under different development models.

Data availability
All data generated or analyzed during this study are included in this published article and its supplementary files.

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Competing interests
The authors declare no competing interests.

Ethical approval
This study did not involve any humans or animals for experimental purposes and is based on a survey-based opinion. Additionally, the research follows the 1964 Helsinki Declaration and its later amendments or comparable ethical standards and has been

approved by the Ethics Committee of the School of Management, Tianjin University of Technology. There was no number attached to the approval.

Informed consent

All individuals invited to participate in the study were provided a statement of informed consent. The informed consent language clearly explained their rights as research subjects/participants. By entering the survey individuals affirmed their consent.

Additional information

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